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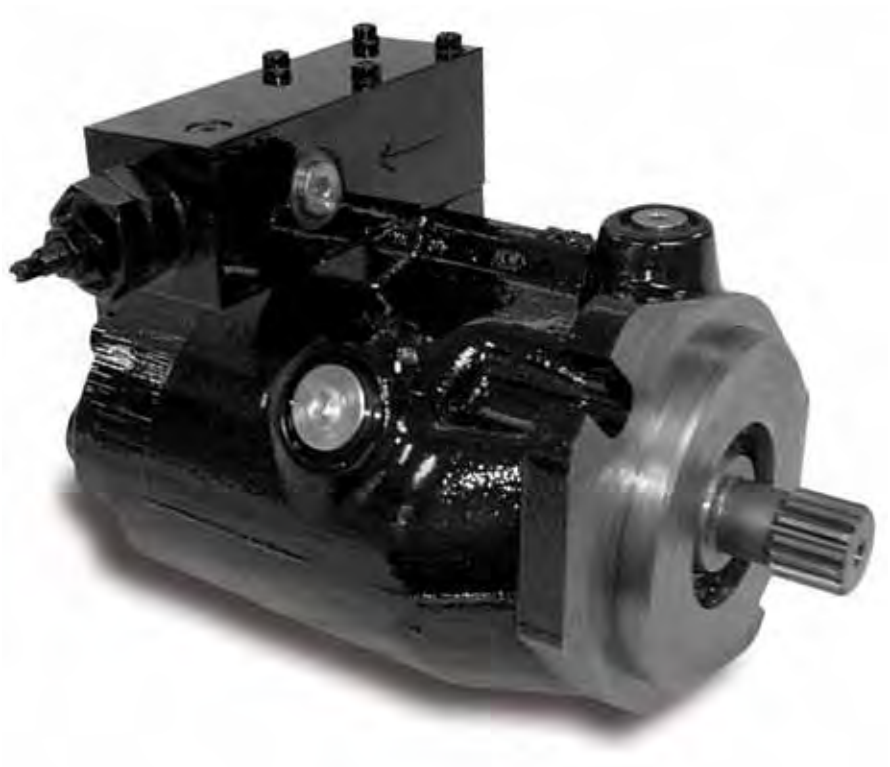
climate control
electromechanical
filtration
fluid & gas handling
hydraulics
pneumatics
process control
sealing & shielding



P1/PD Series – 18cc, 28cc, 45cc Medium Duty Axial Piston Pumps

Variable Displacement – Service Information
Bulletin HY28-2665-02/SVC/EN
Effective: April 01, 2010

Parker

ENGINEERING YOUR SUCCESS.

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P1/PD Series Pump Model			018	028	045
displacement	*maximum*	cm^3/r	18	28	45
outlet pressure	*continuous*	bar	280		
	** intermittent*	bar	320		
	peak	bar	350		
speed (mobile version)	*maximum – boosted inlet*	rpm	—	—	3000
	maximum – 1.0 bar abs inlet	rpm	3200	3200	2600
	maximum – 0.8 bar abs inlet	rpm	2600	2700	2200
	minimum	rpm	600		
speed (industrial version)	*maximum – 1.0 bar abs inlet*	rpm	1800		
	maximum- 0.8 bar abs inlet	rpm	1800		
	minimum	rpm	600		
Inlet pressure	*maximum*	bar	10		
	rated	bar	1.0 absolute (0.0 gage)		
	minimum	bar	0.8 absolute (-0.2 gage)		
case pressure	*peak*	bar	4.0 Absolute (3.0 gage) and less than 0.5 bar above inlet pressure		
	rated	bar	2.0 Absolute (1.0 gage) and less than 0.5 bar above inlet pressure		
fluid temperature	*range*	°C	-40 to +95		
fluid viscosity	*rated*	cSt	6 to 160		
	maximum intermittent	cSt	5000 (for cold starting)		
	minimum intermittent	cSt	5		
fluid contamination	*rated*	ISO	20/18/14		
	maximum	ISO	21/19/16		
SAE mounting	*flange*	SAE	82-2 (A)	101-2 (B)	101-2 (B)
	key shaft	SAE	19-1, (A)	25-1, (BB)	25-1, (BB)
	spline shaft	SAE	9T (A), 11T	13T, (B) 15T, (BB)	13T, (B) 15T, (BB)
ISO mounting	*flange*	ISO	2 bolt 80mm	2 bolt 100 mm	2 Bolt 100mm
	key shaft	ISO	E20N	E25N	E25N
weight	*end port*	kg	13	17	23
	side port	kg	13	18	24
	thru-drive	kg	14	18	27

* Intermittent pressure is defined as less than 10% of operation time, not exceeding 6 successive seconds.

MOUNTING

These pumps are designed to operate in any position. The pump shaft must be in alignment with the shaft of the source driver and should be checked with a dial indicator. The mating pilot bore and coupling must be concentric. This concentricity is particularly important if the shaft is rigidly connected to the driven load without a flexible coupling.

SHAFT INFORMATION

Splined: The shafts will accept a maximum misalignment of 0.15mm, 0.005 inch, total indicator reading. Angular misalignment at the external and internal spline axis must be less than ± 0,002 mm per mm of shaft radius, ± 0.002 inches per inch of shaft radius. The coupling interface must be lubricated. PARKER recommends lithium molydisulfide or similar grease. The internal coupling should be hardened to Rc 27-34 and must conform to SAE-J498c, class 5 flat root side fit.
Keyed: High strength heat treated keys must be used. Replacement keys must be hardened to 27-34 Rc. The key corners must be chamfered 0.81-1.0 mm, 0.032”-0.040”, at 45° to clear radii that exist in the keyway.

SIDE LOAD CAPABILITY

The P1/PD series is designed for inline-drive. Side loading on the shaft is not recommended. If this is unavoidable consult your nearest PARKER representative.

FLUID CONNECTIONS

Connect inlet and outlet lines to the port block of the pump. The maximum case pressure is 2 bar (30 psi) continuous, 4 bar (60 psi) intermittent. The case pressure must never exceed inlet pressure by more than .5 bar (7 psi). When connecting case drain line make certain that drain plumbing passes above highest point of the pump before passing to the reservoir. The case leakage line must be of sufficient size to prevent back pressure in excess of 2 bar (30 psi) and returned to the reservoir below the surface of the oil as far from the supply inlet as possible. All fluid lines, whether pipe, tubing, or hose must be adequate size and strength to assure free flow through the pump. An undersize inlet line will prevent the pump from operating properly at full rated speed. An undersize outlet line will cause back pressure and cause heat generation and increased noise. Flexible hose lines are recommended. If rigid piping is used, the workmanship must be accurate to eliminate strain on the pump port block or to the fluid connections. Sharp bends in the lines must be eliminated wherever possible. All system piping must be cleaned and flushed before installing pump. Make sure the entire hydraulic system is free of dirt, lint, scale, or other foreign material.
Caution: Do not use galvanized pipe. Galvanized coating can flake off with continued use.

SYSTEM RELIEF VALVES

Although the P1/PD series pumps have very fast off-stroke compensator response, system relief valves are recommended in all cases for safety considerations.

RECOMMENDED FLUIDS

The fluid recommended for use in these pumps has a petroleum base and contains agents which provide oxidation inhibition and anti-rust, anti-foam and de-aerating properties as described in PARKER standard HF-1. Where anti-wear additive fluids are specified, see PARKER standard HF-0.

VISCOSITY INDEX

90 V. I. minimum. Higher values extend the range of operating temperature but may reduce the service life of the fluid.

TEMPERATURE

Determined by the viscosity characteristics of the fluid used. Because high temperatures degrade seals, reduce the service life of the fluid and create hazards, fluid temperature should not exceed 110°C (230°F) at the case drain.

MAINTENANCE

The pump is self-lubricating and preventative maintenance is limited to keeping system fluid clean by changing filters frequently. Keep all fittings and screws tight. Do not operate at pressures and speeds in excess of the recommended limit. If the pump does not operate properly, check the troubleshooting chart before attempting to overhaul the unit. Overhauling may be accomplished by referring to the disassembly, rework limits of wear parts, and assembly procedures as provided in this service manual.

FLUID CLEANLINESS

Fluid must be cleaned before and continuously during operation, by filters that maintain a cleanliness level of ISO 20/18/14. Better cleanliness levels will significantly extend the life of the components. As contaminant generation may vary with each application, each must be analyzed to determine proper filtration to maintain the required cleanliness level.

START UP PROCEDURE

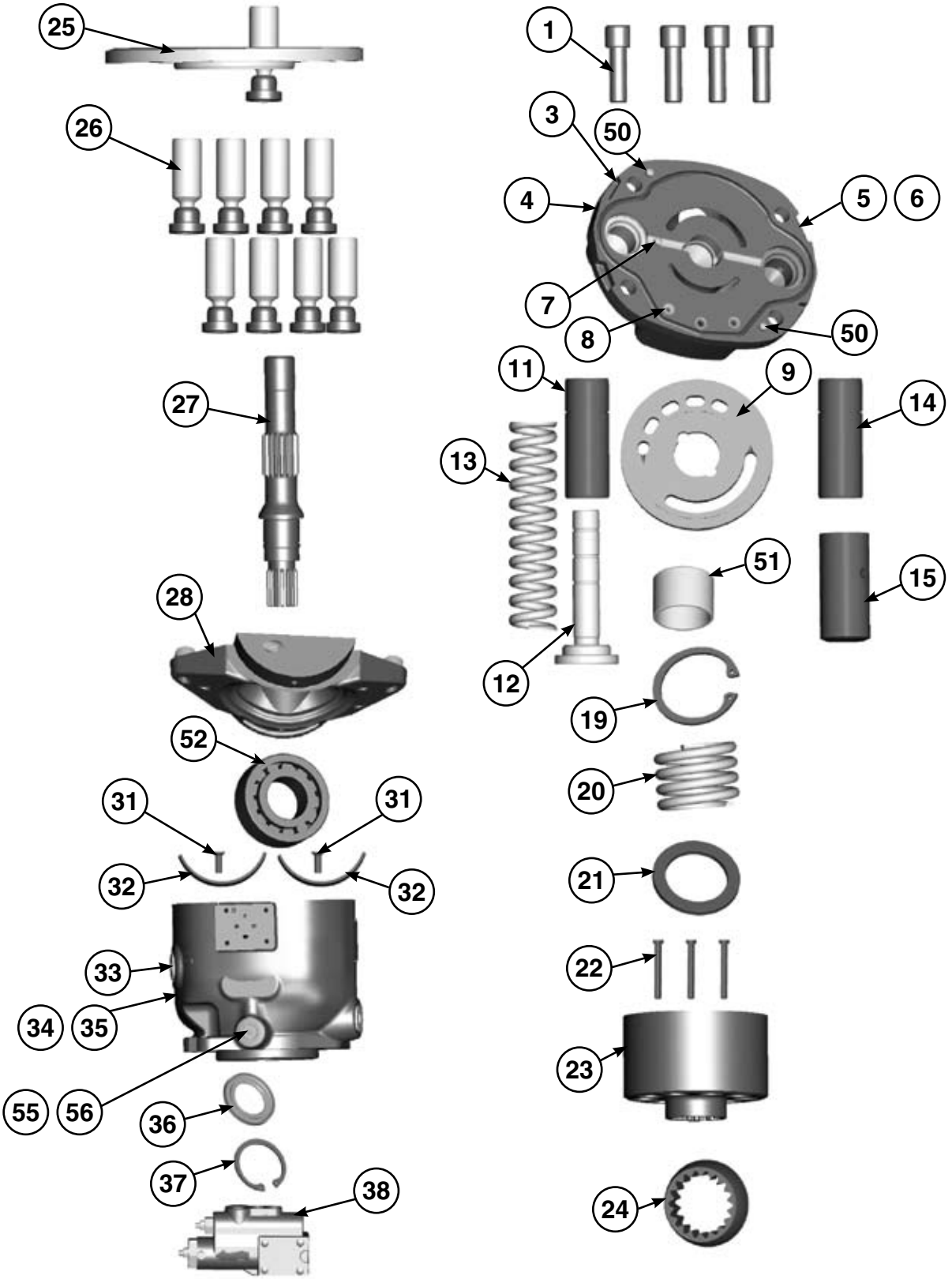
START UP PROCEDURE FOR NEW INSTALLATION

- Read and understand the instruction manual.
- Identify components and their function.
- Visually inspect components and lines for possible damage.
- Insure that all necessary ports are properly connected.
- Check reservoir for cleanliness. Drain and clean as required.
- Check fluid level and fill as required with filtered fluid to a minimum ISO cleanliness level of 20/18/14.
- Fill pump case with clean oil prior to starting.
- If pump is mounted vertically with the shaft up, bleed the air out the D1 drain port located near the mounting flange.
- Check alignment of drive.
- Check oil cooler and activate it, if included in circuit. Check fluid temperature.
- Reduce pressure settings of compensator and relief valve. Make sure accurate pressure readings can be made at appropriate places.
- If solenoids in system, check for actuation.
- Jog the pump drive. Check for proper shaft rotation. Make sure pump fills properly.
- Start the pump drive.
- Bleed system of air. Recheck fluid level.
- Cycle unloaded machine at low pressure and observe actuation (at low speed, if possible).
- Increase pressure settings gradually in steps. Check for leaks in all lines especially in pump and motor inlet lines.
- Make correct pressure adjustments.
- Gradually increase speed. Be alert for trouble as indicated by changes in sounds, system shocks, and air in fluid.
- Equipment is operational.

Component problems and circuit problems are often interrelated. An improper circuit may operate with apparent success but will cause failure of a particular component within it. The component failure can be the effect, not the cause of the problem. This general guide is offered to help in locating and eliminating the cause of problems by studying their effects.

effect of trouble	Possible cause	fault which needs remedy
noisy pump	air in fluid	leak in inlet line low fluid level turbulent fluid return lines above fluid level gas leak from accumulator excessive pressure drop in the inlet line from a pressurized reservoir inlet line strainer acting as air trap
	cavitation in rotating group	fluid too cold fluid too viscous fluid too heavy shaft speed too high inlet line too small inlet strainer too small inlet strainer too dirty operating altitude too high inlet pressure too low
	misaligned shaft	faulty installation distortion in mounting axial interference faulty coupling excessive overhung loads
	mechanical fault in pump	piston and shoe looseness or failure bearing failure incorrect port plate rotation eroded or worn parts in the displacement control
erosion on barrel ports and port plate	air in fluid	see noisy pump above
	cavitation	see noisy pump above
high wear in pump	excessive loads	reduce pressure settings reduce speeds
	contaminant particles in fluid	improper filter maintenance filters too coarse introduction of dirty fluid to system reservoir openings improper reservoir breather improper line replacement
	improper fluid	fluid too thin or thick for operating temperature range breakdown of fluid with time/temperature/shearing effects incorrect additives in new fluid destruction of additive effectiveness with chemical aging
	improper repair	incorrect parts incorrect procedures, dimensions, finishes
	unwanted water in fluid	Condensation faulty breather/strainer heat exchanger leakage faulty clean-up practice water in makeup fluid

effect of trouble	possible cause	fault which needs remedy
pressure shocks	cogging load	mechanical considerations
	worn relief valve	needed repairs
	worn compensator	replace
	slow response in check valves	replace or relocate
	excessive de-compression energy rates	improve decompression control
	Barrel blow-off	rotating group worn, excessive case pressure
compensator instability	excessive line capacitance (line volume, line stretch, accumulator effects)	reduce line size or lengths eliminate hose
heating of fluid	excessive pump leakage	recheck case drain flow and repair as required fluid too thin improper assembly, port timing
	relief valve	set too low (compared to load or to compensator) instability caused by back pressure, worn parts
	compensator	set too high (compared to relief) worn parts
	pump too large for fluid needs	select smaller pump displacement
	heat exchanger	water turned off or too little flow water too hot fan clogged or restricted efficiency reduced by mud or scale deposits intermittent hydraulic fluid flow
	reservoir	too little fluid improper baffles insulating air blanket that prevents heat rejection heat pickup from adjacent equipment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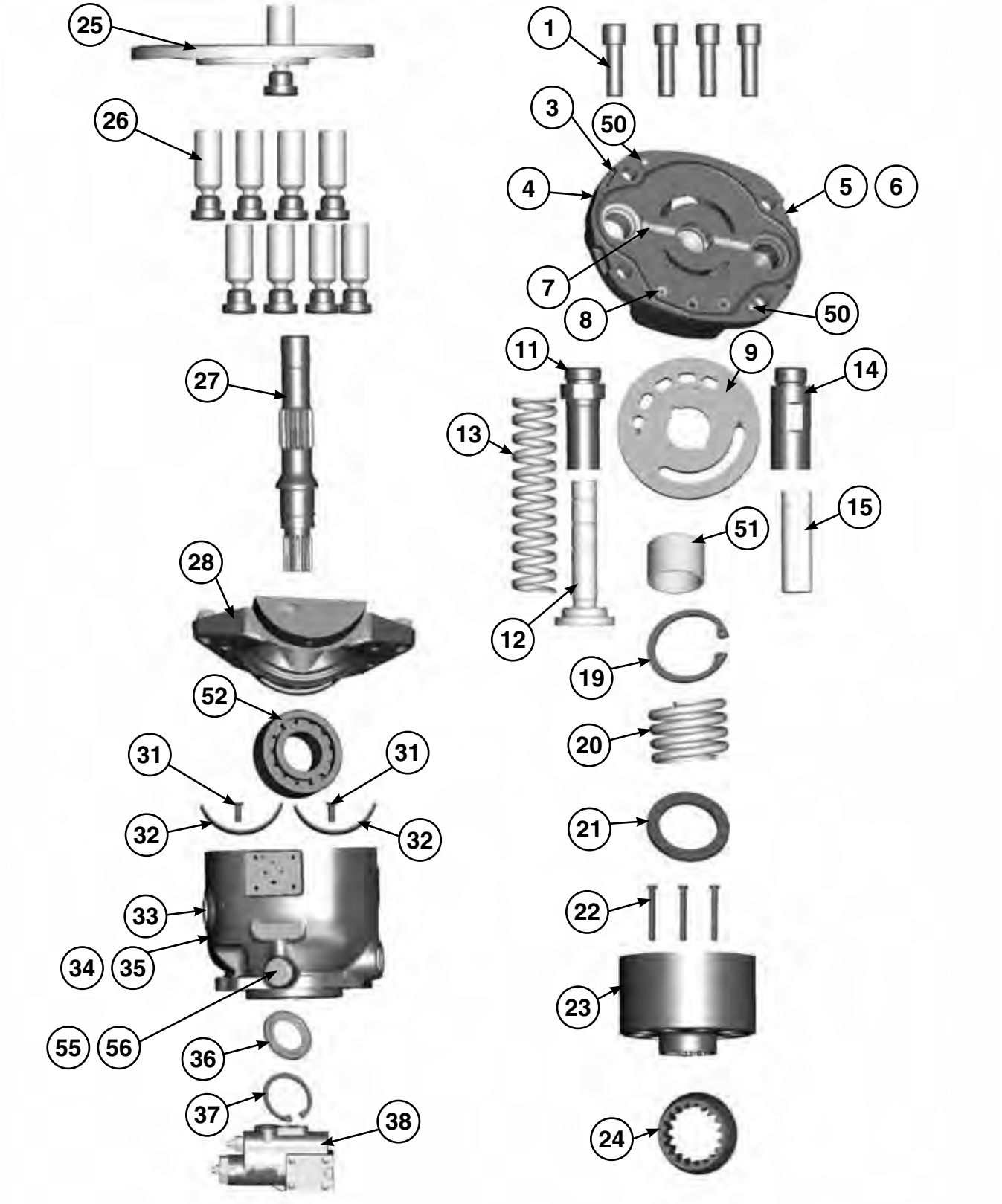
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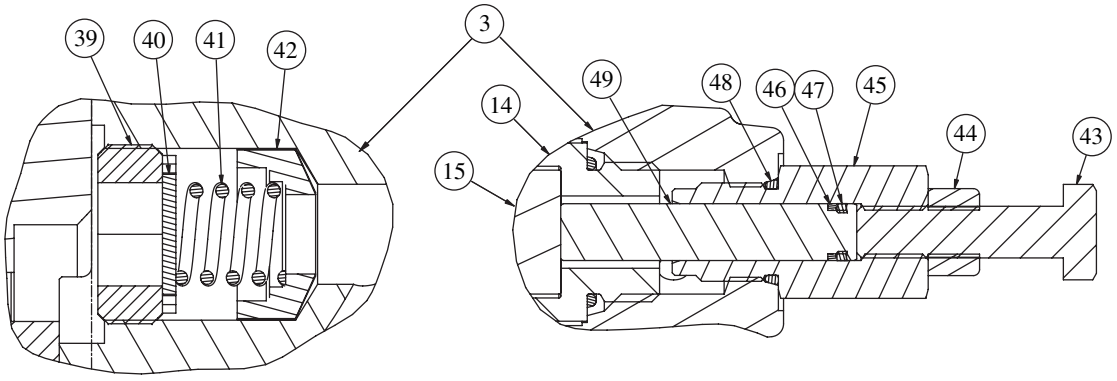
EXPLODED VIEW COMPONENTS						
Item	**Qty**	**018 Part #**	**028 Part #**	**045 Part #**	**Model Code**	**Description**
1	4	210 x 209	210 x 211	361-12229		Socket head cap screw
3	1	N/A	N/A	N/A	P****S***E*2	Port Block S/A End Ported SAE Thread
		N/A	N/A	N/A	P****S***E*0	Port Block S/A End Ported SAE Flange
		N/A	N/A	N/A	P****A,M,B***E*2	Port Block S/A , End Ported Metric Thread
		N/A	N/A	N/A	P****A,M,B***E*0	Port Block S/A , End Ported Metric Flange
		N/A	N/A	N/A	P****S***R*2	Port Block S/A Side Ported SAE Thread
		N/A	N/A	N/A	P****S***R*0	Port Block S/A Side Ported SAE Flange
		N/A	N/A	N/A	P****A,M,B***R*2	Port Block S/A , Side Ported Metric Thread
		N/A	N/A	N/A	P****A,M,B***R*0	Port Block S/A , Side Ported Metric Flange
		N/A	N/A	N/A	P****S***T00A	Port Block S/A Thru Drive SAE A
		N/A	N/A	N/A	P****S***T00B	Port Block S/A Thru Drive SAE B
4	1	2050V-7	2-160V-7	675-00162		O-Ring Face Seal
5	2	108X2V	108X2V	108X2V		(Not shown on port block) O-Ring Boss Plug
7	1	299X67	324-30014-0	324-30014-0		Metric Split Spring Pin
8	3	605-10017-0	605-10017-0	605-10017-0		O-Ring
9	1	03E-94413-0	03E-94969-0	03E-94341-0	P1****R*****E,T	Port Plate CW Mobile
		03E-94965-0	03E-94378-0	03E-95374-0	P1****R*****R	Port Plate CW Mobile with Low Ripple
		03E-94416-0	03E-94970-0	03E-94342-0	P1****L******E,T	Port Plate CCW Mobile
		03E-94966-0	03E-94379-0	03E-95375-0	P1****L*****R	Port Plate CCW Mobile with Low Ripple
		03E-94415-0	03E-94967-0	03E-94339-0	PD****R****E,T	Port Plate CW Industrial
		03E-94963-0	03E-94376-0	03E-94675-0	PD****R*****R	Port Plate CW Industrial with Low Ripple
		03E-94414-0	03E-94968-0	03E-94340-0	PD****L*****E,T	Port Plate CCW Industrial
		03E-94964-0	03E-94377-0	03E-95080-0	PD****L*****R	Port Plate CCW Industrial with Low Ripple
10	2	n/a	n/a	695-00912-0		O-Ring
11	1	03E-94427-0	03E-94390-0	03E-94355-0		Bias Guide
12	1	03E-94428-0	03E-94391-0	03E-94354-0		Bias Piston
13	1	03E-94430-0	03E-94393-0	03E-94356-0		Bias Spring
14	1	03E-94427-0	03E-94390-0	03E-94353-0		Control Guide
15	1	03E-94426-0	03E-94389-0	03E-94352-0		Control Piston
17	1	230-82515-0	789815	230-82227-0		Shaft Bearing
19	1	256X521	256X525	356-65144		Retaining Ring, Internal
20	1	787635	03E-94387-0	03E-94350-0		Barrel Hold Down Spring
21	2	786996	03E-94388-0	03E-94351-0		Barrel Hold Down Washer
22	3	787000	03E-94386-0	03E-94349-0		Barrel Pin
23	1	03E-94717-0	03E-94375-0	03E-94338-0		Barrel - Ductil Iron
24	1	787002	03E-94385-0	03E-94348-0		Ball Seat
25	1	786994	03E-94384-0	03E-94347-0		Slipper Retainer
26	9	See Kits	See Kits	See Kits		Piston Assembly

EXPLODED VIEW COMPONENTS CONTINUED						
27	1	03E-94409-0	03E-94372-0	03E-94335-0	P****01**** E,R	Spline Shaft SAE.
		N/A	N/A	03E-94337-0	P****01****T	Spline Shaft , Thru Drive
		03E-94410-0	03E-94373-0	03E-94948-0	P****02****E,R	Keyed Shaft SAE
		N/A	N/A	03E-94908-0	P****02****T	Keyed Shaft ,SAE , Thru Drive
		22X61	22x22	039-54076-0	P****02****	Key for “02” Shafts
		03E-94800-0	03E-94903-0	03E-94923-0	P****04****E,R	Keyed Shaft ISO
		N/A	N/A	03E-94922-0	P****04***T	Keyed Shaft , ISO, Thru Drive
		03E-94434-0	03E-95199-0	03E-94360-0	P****04****	Key For “04” ISO Shafts
		03E-94718-0	N/A	N/A	P****06**** E,R	Spline Shaft SAE A , 9T
		03E-94804-0	03E-95166-0	03E-94990-0	P****08**** E,R	Spline Shaft SAE B , 13T
		N/A	N/A	03E-95197-0	P****08**** T	Spline Shaft SAE B , Thru Drive
28	1	S2E-18416-0	S2E-18414-0	S2E-18412-0		Cam Plate Assembly
31	2	03E-94359-0	03E-94359-0	03E-94359-0		Bearing Retainer Orifice Screw
32	2	03E-94432-0	03E-94395-0	03E-94358-0		Cam Bearing
33		N/A	N/A	N/A		Housing (Not Sold Separately)
34	2	108X6	108X8	488-35055-0		O-Ring Boss Plug
35	2	3-906V-9	695-00908-0	695-00910-0		O-Ring
36	1	787140	P2-060-3304	620-82125-5		Shaft Seal (Viton)
37	1	256x535	256X544	356-65158-0		Retaining Ring, Internal
38	1	S2E-17904-5T			P*******R****C00	Pressure Compensator, 80-280 Bar ,CW
	1	S2E-17905-5T			P*******L****C00	Pressure Compensator, 80-280 Bar, CCW
	1	S2E-18285-5T			P*******R****C10	Pressure Compensator, 20-80 Bar ,CW
	1	S2E-18286-5T			P*******L****C10	Pressure Compensator, 20-80 Bar, CCW
	1	S2E-18745-5T			P*******R****AM0	Remote Compensator, CW
	1	S2E-18746-5T			P*******L****AM0	Remote Compensator, CCW
	1	S2E-17823-5T			P***S***R****L00	Load Sense, CW , SAE
	1	S2E-17824-5T			P***S***L****L00	Load Sense, CCW , SAE
	1	S2E-17936-5T			P***A,B***R****L0	Load Sense, CW , BSPP
	1	S2E-17937-5T			P***A,B***L****L0	Load Sense, CCW , BSPP
	1	S2E-18584-5T			P***S***R****L2	Load Sense w/ Bleed, CW , SAE
	1	S2E-18586-5T			P***S***L****L2	Load Sense w/ Bleed, CCW , SAE
50	2	324-30024-0	324-30024-0	324-30014-0		Dowel Pin, Cover
51	1	216-10013	789814	230-82227-0		Bushing, Port Block
52	1	230-82514-0	789815	230-82516-0		Cylindrical Roller Bearing
53	1	256X222	256X221	356-65159-0		Retaining Ring, External
54	1	256X544	256X544	n/a		Retaining Ring, Internal
55	1	108X4	108X4	108X4		O-Ring Boss Plug
56	1	3-904V-9	3-904V-9	3-904V-9		O-Ring



CASE TO INLET CHECK VALVE, 018, 028, 045				
Item No	**Quanty**	**Part Number**	**Model Code**	**Description**
39	1	314-10002-0	P******E,R,T*1,3	Hollow Set Screw
40	1	03E-94720-0	P******E,R,T*1,3	Check Valve Poppet
41	1	03E-94721-0	P******E,R,T*1,3	Spring
42	1	03E-94722-0	P******E,R,T*1,3	Check Valve Stop

Minimum and Maximum Displacement Stop						
Item No	**Quantity**	**018 Part Number**	**028 Part Number**	**045 Part Number**	**Model Code**	**Description**
43	1	362-11045-0			P******E,R1,2,3	Adjusting Screw
44	1	334-00013-0			P******E,R1,2,3	Locknut
45	1	03E-93181-0			P******E,R1,2,3	Volume Stop Plug
46	1	695-00011-0			P******E,R1,2,3	O-Ring
47	1	618-15023-0			P******E,R1,2,3	Back Up Ring
48	1	695-00908-0			P******E,R1,2,3	O-Ring
49	1	03E-94736-0	03E-95170-0	03E-93262-0	P******E,R1,3	Max Volume Stop Rod
49	1	03E-95217-0	03E-95358-0	03E-93262-0	P******E,R2,3	Min Volume Stop Rod
50	2	488-35018-0			P*045**U*E,R0	Plug , Not Shown

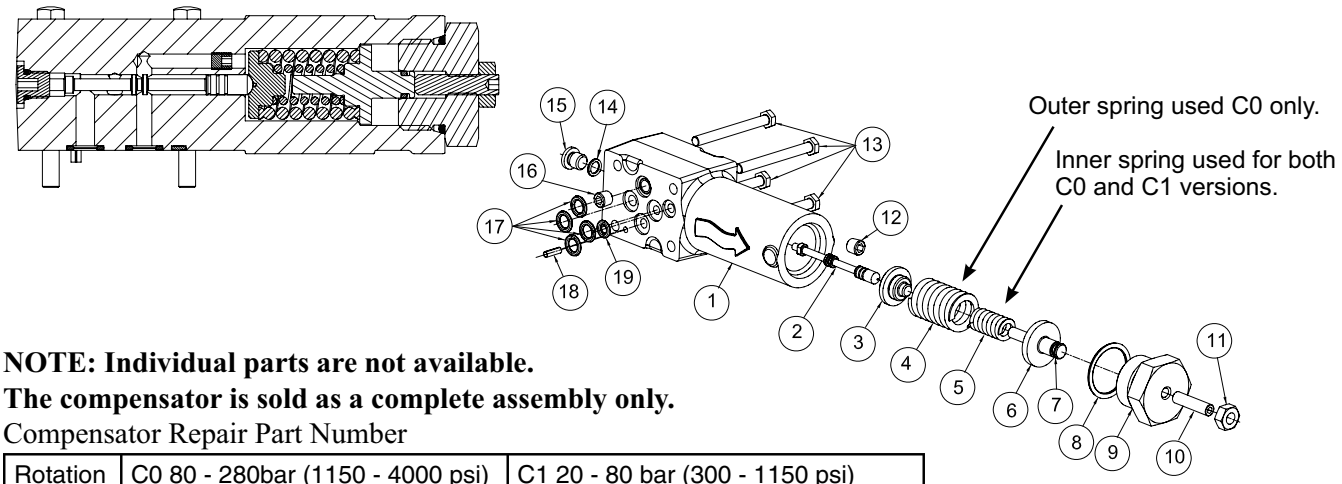
Thru Drive Pad and Coupling	Model Code	Thru Drive Couplings			O-Ring
		018	028	045	
SAE A Thru Drive , 9T Spline	P******T**A	N/A	N/A	03E-94942-0	695-00237-0
SAE A Thru Drive , 11T Spline	P******T**H	N/A	N/A	03E-94943-0	695-00237-0
SAE B Thru Drive , 13T Spline	P******T**B	N/A	N/A	03E-94945-0	695-00243-0
SAE BB Thru Drive , 15T Spline	P******T**Q	N/A	N/A	03E-94361-0	695-00243-0

	Model Code	018	028	045
Adjustable Displacement Kits	P*****1,2,3	S2E-19203-5	S2E-19204-5	S2E-19114-5K
Seal Kits	P****S**5	S2E-18709-5K	S2E-19198-5K	S2E-19066-5K

Rotating Group Kits	Model Code	018	028	045
CW Mobile	P1****R*****E,T	S2E-18710-0K	S2E-19119-0K	S2E-19067-0K
CW Mobile with Low Ripple	P1****R*****R	S2E-19205-0K	S2E-19209-0K	S2E-19235-0K
CCW Mobile	P1****L******E,T	S2E-18711-0K	S2E-19120-0K	S2E-19068-0K
CCW Mobile with Low Ripple	P1****L*****R	S2E-19206-0K	S2E-19210-0K	S2E-19236-0K
CW Industrial	PD****R****E,T	S2E-18712-0K	S2E-19121-0K	S2E-19069-0K
CW Industrial with Low Ripple	PD****R*****R	S2E-19207-0K	S2E-19211-0K	S2E-19126-0K
CCW Industrial	PD****L*****E,T	S2E-18713-0K	S2E-19122-0K	S2E-19070-0K
CCW Industrial with Low Ripple	PD****L*****R	S2E-19208-0K	S2E-19212-0K	S2E-19127-0K
Rotating Group Kit includes barrel s/a, pistons, retainer, washer, pins, port plate				

Torque Limiter Control Kits	Model Number	018	028	045
Torque Limiter Kit for AMT Control	P*045AMT	N/A	N/A	S2E-19102-5
Torque Limiter Kit for ALT Control	P*045ALT	N/A	N/A	See Note

Note: “AL*” control can be converted from “AM*” control with spool conversion kit S2E-19117-0



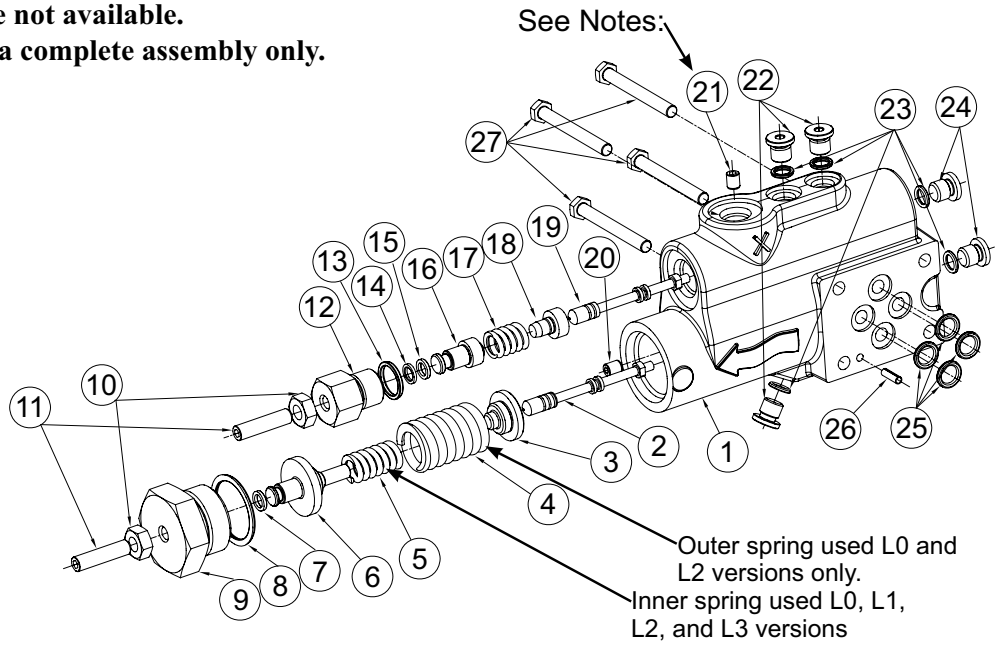
NOTE: Individual parts are not available.
The compensator is sold as a complete assembly only.

Compensator Repair Part Number

Rotation	C0 80 - 280bar (1150 - 4000 psi)	C1 20 - 80 bar (300 - 1150 psi)
CW	S2E-17904-5 T	S2E-18285-5 T
CCW	S2E-17905-5 T	S2E-18286-5 T

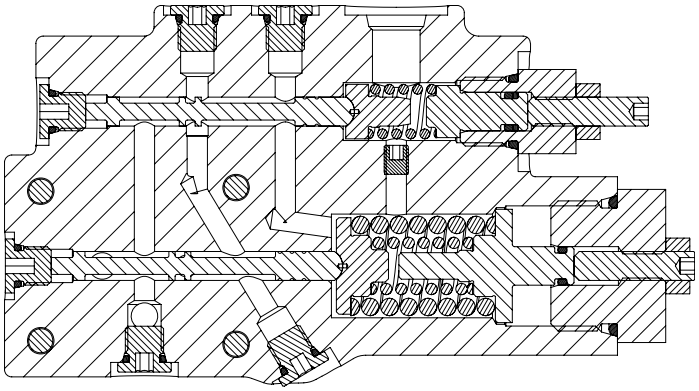
Item no.	Quantity	Description	NOTES / Tightening Torque
1	1	Compensator body CW rotation	
		Compensator body CCW rotation	
2	1	Spool	
3	1	Spring seat	
4	1	Outer spring	C0 versions only
5	1	Inner spring	
6	1	Spring seat & piston	
7	1	Seal piston o-ring	
8	1	Spring cap o-ring	
9	1	Spring cap	115 ± 7 N-m (85 ± 5 ft-lbs)
10	1	Adjusting screw	
11	1	Adjusting screw locknut	7.9 ± 0.8 N-m (70 ±7 in-lbs)
12	1	Socket set screw	(Loctite 242) 3.4 ± 0.4 N-m (30 ± 3 in-lbs)
13	4	Hex mounting screw	5.0 ± 0.3 N-m (45 ± 3 in-lbs)
14	1	SAE #2 o-ring	
15	1	Hardened SAE #2 o-ring boss plug	4.0 ± 0.6 N-m (35 ± 5 in-lbs)
16	1	Orifice plug	(Loctite 242) 3.4 ± 0.4 N-m (30 ± 3 in-lbs)
17	4	Teflon O-ring	
18	1	Roll pin	
19	1	Teflon O-ring	

NOTE: Individual parts are not available.
The compensator is sold as a complete assembly only.



Compensator Repair Part Number

Port	Rotation	L0 80 - 280bar (1150 - 4000 psi)	L2 80 - 280bar (1150 - 4000 psi)
SAE	CW	S2E-17823-5 T	S2E-18584-5 T
	CCW	S2E-17824-5 T	S2E-18586-5 T
ISO	CW	S2E-17939-5 T	N/A
	CCW	S2E-17938-5 T	N/A
BSPP	CW	S2E-17937-5 T	N/A
	CCW	S2E-17936-5 T	N/A



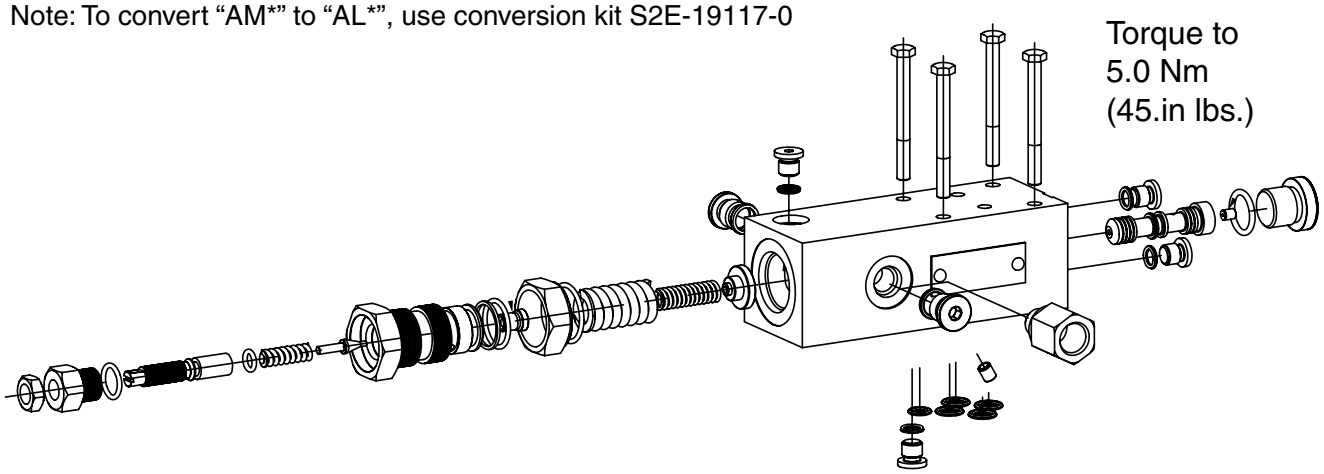
8	1	Main Compensator Spring cap o-ring		
9	1	Main Compensator Spring cap	115 ± 7 N-m (85 ± 5 ft-lbs)	
10	2	Adjusting screw		
11	2	Adjusting screw locknut	7.9 ± 0.8 N-m (70 ±7 in-lbs)	
12	1	Load Sense Compensator Spring cap	36.5 ± 1.5 N-m (27 ± 1 ft-lbs)	
13	1	Load Sense Compensator Spring cap or-ing		
14	1	Load Sense Compensator Piston backup ring		
15	1	Load Sense Compensator Piston Oring		
16	1	Load Sense Compensator Seal Piston		
17	1	Load sense compensator spring		
18	1	Load sense compensator spring seat		
19	1	Load sense compensator spool		
20	1	Socket set screw	(Loctite 242) 3.4 ± 0.4 N-m (30 ± 3 in-lbs)	
21	1	Socket set screw	L0 versions	(Loctite 242) 3.4 ± 0.4 N-m (30 ± 3 in-lbs)
		Orifice	L2 versions	
22	3	SAE #2 o-ring boss plug	4.0 ± 0.6 N-m (35 ± 5 in-lbs)	
23	5	SAE #2 o-ring		
24	2	Hardened SAE #2 o-ring boss plug	4.0 ± 0.6 N-m (35 ± 5 in-lbs)	
25	4	Teflon O-ring		
26	1	Roll pin		
27	4	Hex mounting screw	5.0 ± 0.3 N-m (45 ± 3 in-lbs)	

NOTE: Individual parts are not available.
The compensator is sold as a complete assembly only.

Compensator Repair Part Number

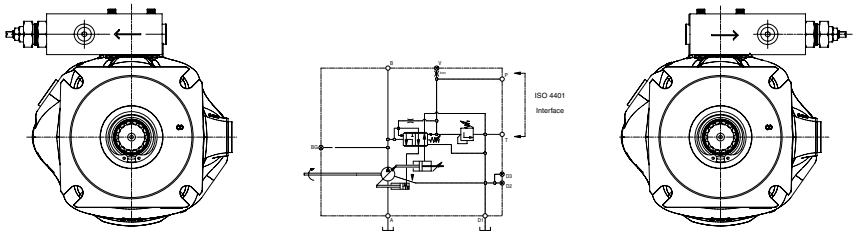
Rotation	AM*	AN*	AL*	AE*	AF*
CW	S2E-18745-5T	S2E-18743-5T	S2E-19107-5T	S2E-18747-5T	S2E-18749-5T
CCW	S2E-18746-ST	S2E-18744-5T	S2E-19108-5T	S2E-18748-5T	S2E-18750-5T

Note: To convert "AM*" to "AL*", use conversion kit S2E-19117-0

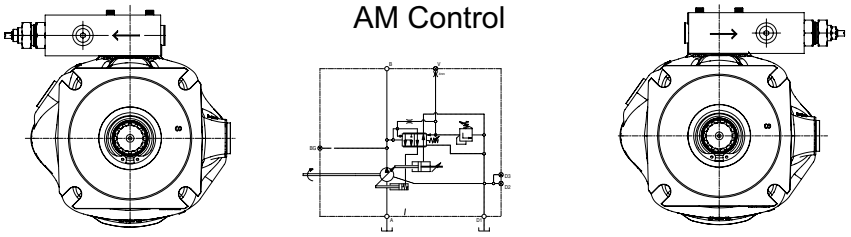


CCW DIRECTION OF ROTATION CW

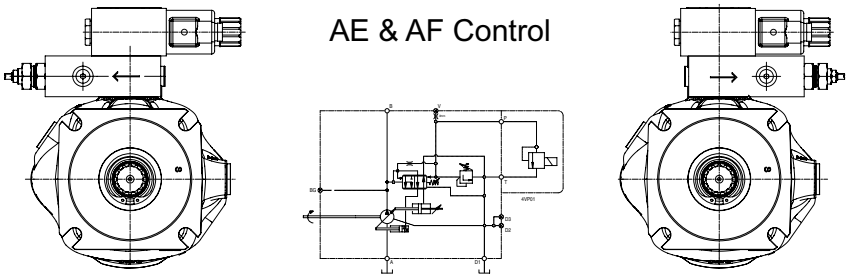
AN Control



AM Control



AE & AF Control



Pump disassembly for inspection should be limited to the following cases:
a) Malfunction or oil leakage resulting from damage or wear and tear.
b) Trouble-shooting procedures previously listed do not solve the problem.

For rotation change or shaft conversion, disassembly should be done only as far as necessary to complete conversion.

Disassembly and reassembly should be performed in a clean environment.

> **Caution:** Spring assemblies in the pump are normally set under high compression and bodily injury may occur if caution is not taken during disassembly.

It is usually not necessary to replace spring (20) fitted in cylinder barrel. Do not replace the spring unless absolutely necessary.

After disassembly, the internal parts should be coated with a film of clean oil and protected from dirt and moisture.

It is recommended that the length of the protruding portion of the compensator adjusting screws, on the control 38 be measured and noted as this information will prove useful during assembly.

Care must be taken to avoid dropping, damaging or contaminating the machined parts and the control valve.

For complete overhaul, all o-rings and seals should be discarded and replaced.

1. Identify the pump from information on the data tag. Figure 1

Figure 1

2. Drain fluid from housing. Fluid drained from pump should be disposed of properly.
3. Mount pump in fixture to prevent movement while removing main housing bolts
4. Remove bolts holding the compensator assembly on the pump housing. Additional fluid may drain out of the passages when the compensator is removed. Set compensator aside for later disassembly and inspection
5. Remove the bolts attaching the port block to the main housing.
6. Carefully remove the port block. Use caution to avoid dropping the port plate. Note the location of the bias spring - piston assembly and the control piston assembly. The control piston, bias piston and bias spring may remain in pump when port block is removed. Remove and discard the three white Teflon seals on the port block. These seals should be replaced each time the pump is disassembled.
7. Remove the control piston and the bias piston - spring assembly.
   NOTE: For rotation change only, do not disassemble further, proceed to step 16.
8. Position the pump horizontally and remove the rotating group. Avoid separating the pistons from the barrel if possible. This will assist in identifying damage between an individual piston and bore during component inspection.

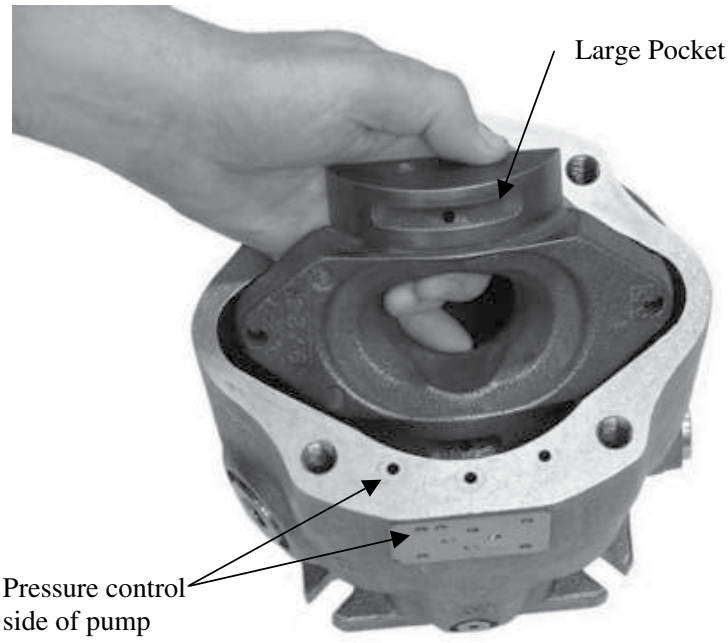


Figure 2

DISASSEMBLY PROCEDURES
Continued

9. Remove Cam from housing.
10. Remover cam bushing screws and cam bushings from pump.
11. Remove snap ring in housing and shaft bearing assembly.
12. If completing a seal change or complete overhaul, turn the housing over and remove the snap ring and shaft seal from the housing. Note: Install a new seal do not reuse the shaft seal.
13. If there is excessive wear on the port block bushing; remove the bushing from the port block.
14. If complete overhaul or rotation change, remove control piston and bias piston guides. (45 Size only)

COMPENSATOR DISASSEMBLY

NOTES: Access plugs on end of compensator spool bores are hardened plugs. Do not interchange with other plugs in the control. For rotation change, the complete compensator assembly will need to be replaced.

1. Measure and record the extension of the two pressure adjusting screws.
2. Carefully remove the main compensator spring cap. Remove the two springs. Remove the seal piston and spring seat. Remove the o-ring boss access plug on the opposite side of the compensator. Remove the compensator spool. NOTE: the compensator spool and inner spring are not interchangeable with the load sense compensator spool and spring.
3. Load sense compensator: Carefully remove the load sense compensator spring cap with spring seat/seal piston. Remove the spring. Remove the spring seat. Remove the o-ring boss access plug on the opposite side of the compensator. Remove the load sense compensator spool. NOTE: the load sense compensator spool and spring are not interchangeable with the main compensator spool and inner spring of the main compensator.
4. Remove all SAE o-ring boss access plugs.

Proceed to inspection section of this manual.

INSPECTION

Carefully clean and dry all parts prior to inspection. Refer to chart 1 for dimensional information regarding allowable tolerances.

1. Examine piston diameters for scratches or gouges. If any piston is severely-damaged, note which piston bore it came out of. Extra attention should begiven to that bore in step 2. Check end play of piston shoe assembly. Checkthe bottom surface of the shoes for damage. The shoe surface should besquare and flat. Measure the depth of the pocket of the shoe. Shoes may belapped as a set if the pocket depth is within allowable limits. Confirm pocketdepth after lapping to insure it is still within limits.
2. Examine bores in cylinder for scratches Check diameter of bores in 4different locations, including near the bottom of the barrel where the pistondoes not travel. If the dimensions vary by more than 0.0102 mm (0.0004 in.)or any dimension exceeds the allowable limit, the barrel needs to bereplaced. Examine the barrel face for scratches and gouges. The barrel canbe reworked if dimensions are with specifications listed in chart 1.
3. The port plate can be lapped lightly if the face is only lightly scratched, otherwise it should be replaced.
4. Examine the retainer plate in the area of contact with the piston shoes. Anymarks beyond light polishing indicate that replacement is necessary. Check the surface of the spherical area of the retainer plate and the spherical guide ball. Inspect the back surface of the spherical guide ball where the load pins make contact. If indentations are present replace the guide ball.
5. Examine cam on top and bottom surface. If scratches or gouges appear to penetrate the surface treatment, the cam must be replaced.
6. The cam bearings cannot be reworked and should be replaced if worn through the Teflon surface.
7. Both the bias piston and the compensator piston should move freely in their respective bores. The pistons and bores should be free of scratches or gouges.
8. The seal area of the drive shaft should be smooth and not have marks due to seal wear. Keyed shafts should be inspected for signs of brinelling and damage to the key area. Splined shafts may have a contact wear pattern but should not show excessive wear on the spline area.
   NOTE: Spinning on shaft for P1/PD-018, 028 and 045 the cylindrical bearing should not have any signs of roller spalling, brinelling or discoloration. The bearing should be free to rotate without bind or rough feel.

COMPENSATOR INSPECTION

NOTE: The compensator is supplied as an assembly. Individual parts are not available. If there is significant damage to any of the parts, the complete compensator will need to be replaced.

1. Inspect the main compensator spool and the load sense spool for scratches or other damage.
2. Inspect the springs for proper free extension length (see chart).
3. Inspect the spool bores for damage. Apply a light oil film on the appropriate spool and check its fit in the bore. The spool should fit snugly in housing and not have any radial play.

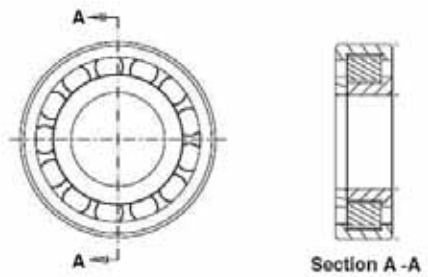
Chart 1
Rework Limits

Item Number	Component	018 Part No	028 Part No	045 Part No	Tolerances
20	Barrel Spring	787635	03E-94387-0 39.5 mm	03E-94350-0 48.3 mm	Free Height +/- .2mm
13	Bias Spring	03E-94430-0 78.3 mm	03E-94393-0 87.5 mm	03E-94356-0 116.4 mm	Free Height +/- .2mm
26	Piston	Max End Play 0.10 mm Min Shoe Flange Thickness 2.97 mm	Max End Play 0.07 mm Min Shoe Flange Thickness 3.98 mm	Max End Play 0.10 mm Min Shoe Flange Thickness 4.98 mm	Measure OD in 3 places, top, middle and bottom. Measurement should not vary by more than .01 mm End Play between piston and shoe should not exceed value shown
23	Barrel	03E-94717-0	03E-94375-0	03E-94338-0	Measure piston bore ID in 3 places , top, middle, bottom. Measurement should not vary by more than 0.01 mm. Max material to be removed by lapping is .0051 mm
C0	P Max Compensator Spring-Outer	03E-93158-0 39 mm			Free Height : +/- .2mm
C0	P Max Compensator Spring- Inner	03E-93159-0 26 mm			Free Height : +/- .2mm
L0	Load Sense Spring	03E-93825-0 14 mm			Free Height : +/- .2mm

For major overhauls, all plugs should be removed, and the seals replaced. Prior to assembly, all parts should be thoroughly cleaned. Assembly should be performed in a clean work environment.

Do not use bearing grease during installation. Grease does not dissolve in hydraulic oil and may plug orifices or filters in the system. Clean petroleum jelly is preferred to lubricate o-rings and seals, and to adhere parts for assembly.

NOTE: For fluids other than petroleum based hydraulic oil, insure that petroleum jelly is compatible with the fluid. If not compatible, another product should be used instead.



Cylindrical Bearing

Inspect all bearing surfaces and seal areas to insure that they are free from nicks, dings, scratches, and rust.

1. The P1/PD-018, 028 and 045 assembly will use step 2 to install the shaft seal. For P1/PD-018, 028 and 045 front bearing installation go to step 3.
2. Turn housing over. Using installation tool T1, press the shaft seal in the seal bore. Install the snap ring into the groove in the seal housing bore.
3. Install cylindrical bearing on pump shaft (slip fit). Install external retaining ring to hold bearing in place on the shaft. Insert shaft assembly into the pump housing with the bearing sliding into the bearing diameter in the housing. Install internal retaining ring into the housing.
4. If barrel hold down spring was removed during disassembly process, install three pins to slots in barrel spline (45 Size only). Petroleum jelly can be used to hold pins in place while installing remaining parts. (Figure 4) Place barrel on fixture with pin side down. Install backup washer and hold down spring and second back up washer. Compress spring in press and install snap ring. Caution: Make sure snap ring is properly seated in groove prior to removing barrel from press.

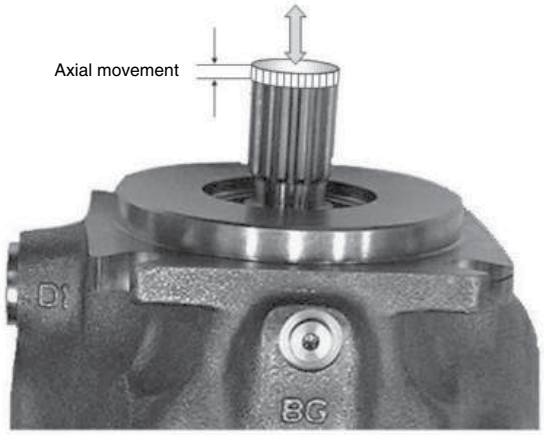


Figure 4

Chart 3	
Pump	Control and bias guide torque
018	Press Fit
028	Press Fit
045	142 N.M./105 ft lbs

5. Apply a light film of oil into the piston bores. Lightly lubricate the spherical surface of the guide ball. Install the nine pistons into the bores in the hold down plate. Install the spherical guide ball into the hold down plate. While holding the guide ball against the hold down plate, install the pistons into the barrel.
6. Install the locating pin on the port block face.
7. For 045: Apply Loctite Primer Grade T to guide threads and allow to dry. Install unlubricated o-rings on the control guide and bias guide. Apply Loctite 271 to guide threads. For left hand rotation the bias guide is installed nearest to the dowel pin (figure 5A.) For right hand rotation the control guide is installed nearest to the dowel pin (figure 5B.) Torque the control and bias guides as specified in Chart 3. For 018, 028: The guides are identical and press fit into the holes. (Not shown in picture below)

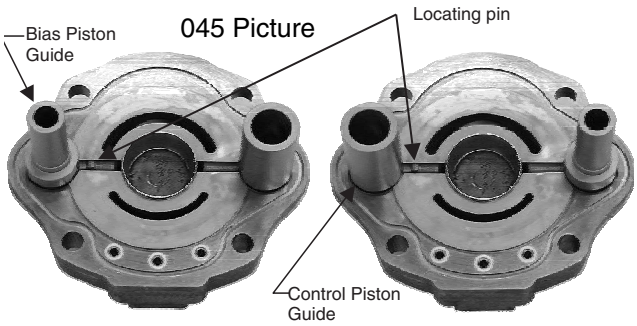


Figure 5A
Port Block with Left Hand configuration

Figure 5B
Port Block with Right Hand configuration

8. Apply light oil film to control piston and install it in the control guide bore.
9. Apply light oil film to the bias piston. Install the bias spring and the bias piston in the bias piston guide bore.
10. Apply a light layer of petroleum jelly to the back surface of the port plate. Install the port plate on the port block, lining up the slot on the port plate with the locating pin. (Ref Figure 6)
11. Install the large o ring in the groove on the port block. Install the three teflon o rings on the pressure communication ports of the port block.
12. Install the cam bearings in the cradle area of the housing. The chamfer on the back of the bearing must face the outer wall of the housing. Use Loctite Primer Grade “T” or other suitable primer on screws and mating threads in housing. Apply Loctite #242 (use sparingly) to screw threads and install orifice screws to hold bearings in place. Torque screws to 3.4 ± 0.25 Nm (33 ± 3 in-lb).
13. Place thin film of clean oil on cam bearing surfaces. Install cam in housing. For 045, the cam must be tilted to permit entry into the housing. (Figure 2) NOTE: The large pocket on the bottom surface of the cam must be on the same side as the three pressure communication holes on the main housing. Pump rotation does not affect the assembly of the cam.
14. Install the drive shaft into the pump housing. Position pump horizontally. Install the rotating group over the pump shaft. Rotate the barrel to insure that it is seated against the cam. Insure that the pump shaft is seated properly in the front bearing.

Chart 4	
Pump	Housing bolt torque
018	51 N.M./38 ft lbs
028	70 N.M./52 ft lbs
045	85 N.M./63 ft lbs

15 Confirm that compensator rotation, port plate rotation, control and bias piston location indicate same direction of rotation.

16 Carefully install the assembled port block on the pump housing. Press the port block to compress the bias spring and install housing bolts. Tighten the bolts in a cross pattern to insure the port block does not get cocked on the housing. When port block is seated on the housing, torque bolts in a cross pattern as specified in chart 4.

17. Install o-ring seals and assembled compensator on side of pump housing. Pump rotation is indicated by arrow on compensator housing. Torque bolts to 5 ± 0.25 Nm (45 ± 3 in-lb). (See Figure 7)

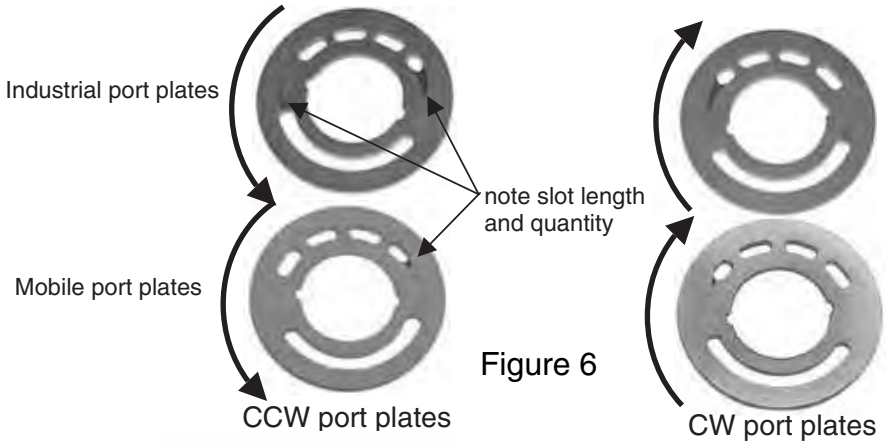


Figure 6

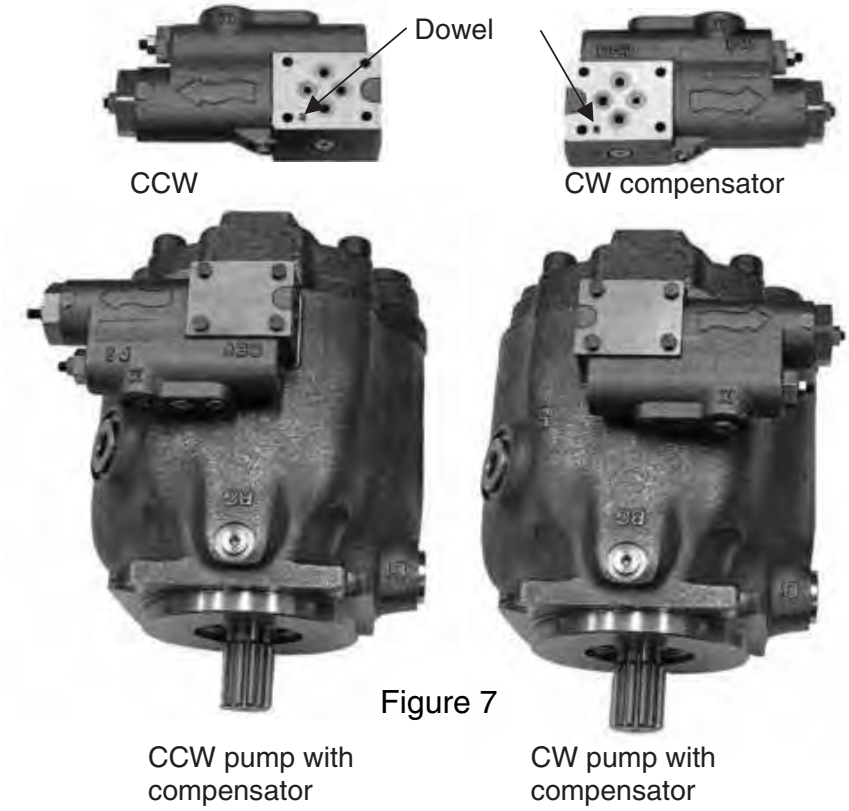


Figure 7

COMPENSATOR ASSEMBLY

NOTE: instructions are for load sense compensator. for other compensator types disregard steps related to extra spool assembly.

Carefully clean and dry all parts prior to assembly. Use caution to insure that spools and other parts are not damaged during cleaning process. Use clean oil to lubricate seals and spools for easier assembly.

1. Remove and discard all o-rings. Install new o-rings on SAE boss plugs and seal pistons.

2. Apply a light film of oil to the o-ring on the main compensator seal piston. Install the main compensator seal piston in the main compensator spring cap.

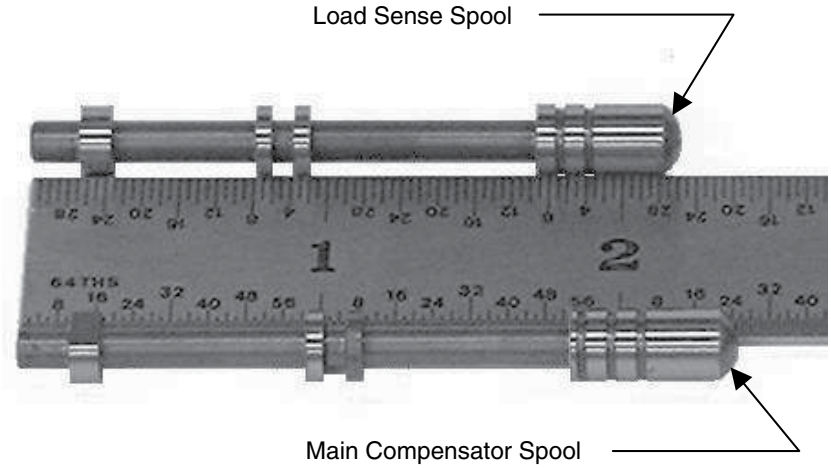
3. Place inner compensator spring on seal piston. Install the outer compensator spring over the inner spring on the seal piston. Position the spring seat over the springs. Insert this assembly into the main compensator housing bore. Torque the main compensator spring cap to 169-183 Nm (125-135 ft.-lb.).

4. Apply a light film of oil on the main compensator spool (the longer of the 2 spools). Insert the spool into the spool bore opposite the main compensator spring assembly in the compensator body. The rounded end of the spool should be installed first so it will contact the spring seat. Install a new o-ring on the hardened SAE boss fitting and place it into the port. Torque fitting to 4 ± 0.5 Nm (37 ± 5 in-lb).

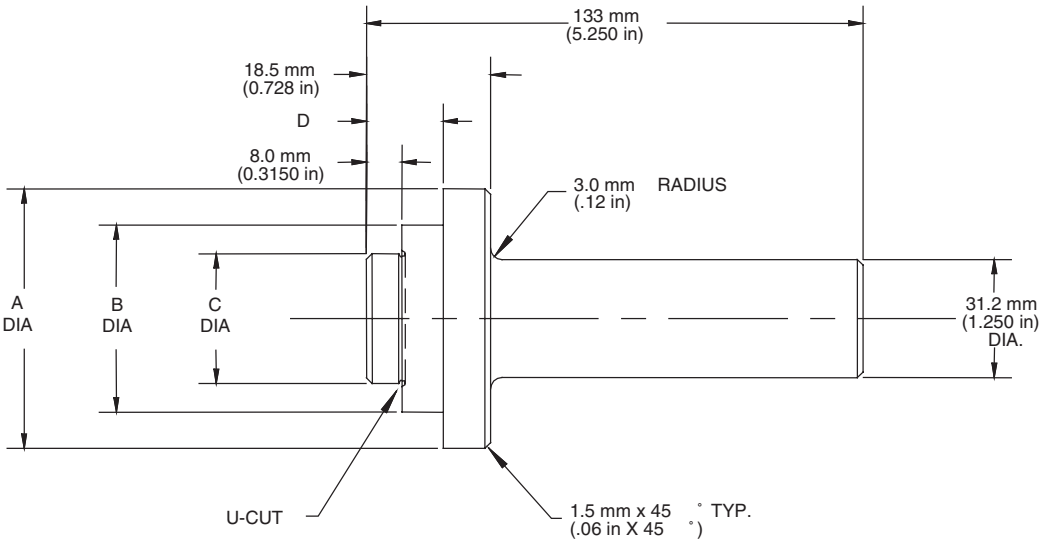
5. Apply a light film of oil to the o-ring on the load sense seal piston. Install the load sense compensator seal piston seat in the load sense spring cap. Install the load sense spring over the seal piston. Position the spring seat over the spring. Install this assembly into the load sense bore of the compensator housing. Torque the load sense spring cap to 35-38 Nm (26-28 ft. lb.).

6. Apply a light film of oil to the load sense compensator spool (the shorter of the 2 spools). Insert the spool into the spool bore opposite the load sense spring assembly. The spool should be installed with the rounded end in first so it will contact the load sense spring seat. Install a new o-ring on the hardened SAE boss fitting and place it into the port. Torque fitting to 4 ± 0.5 Nm (37 ± 5 in-lb).

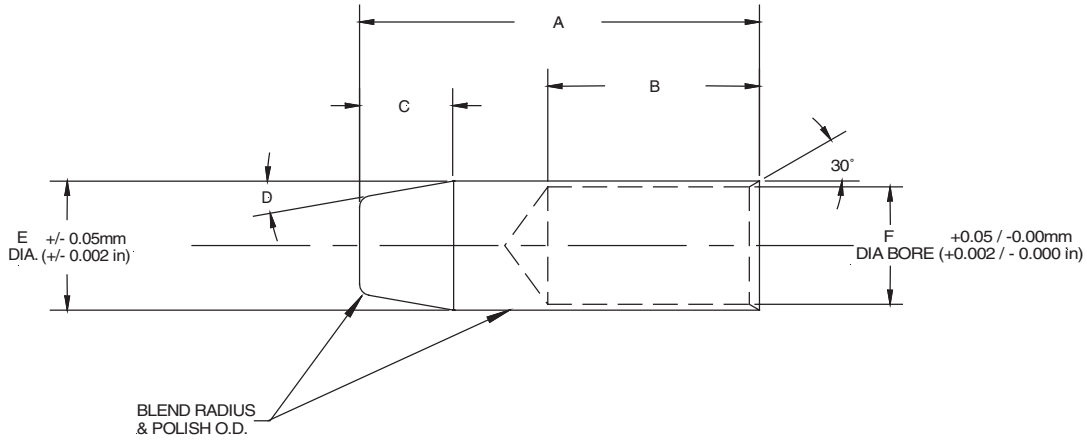
7. Install o-rings on remaining SAE boss fittings and install into housing. Torque SAE-2 fittings to 4 ± 0.5 Nm (37 ± 5 in-lb).



Parker Hannifin Corporation
Hydraulic Pump Division
Marysville, Ohio USA

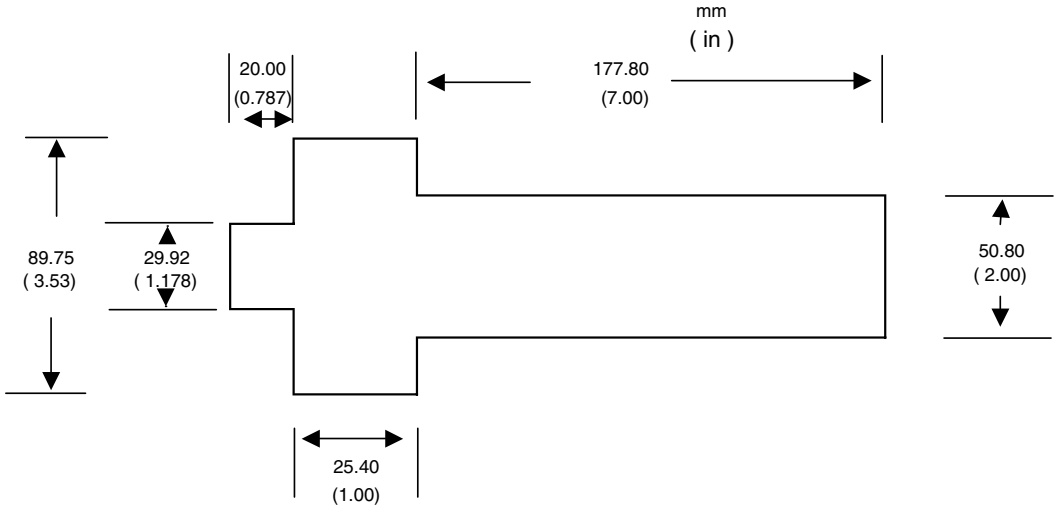


T1 Seal installation tool	A	B	C	D
(018)	2.250	1.62	1.18	0.406
(028)	2.250	2.00	1.378	0.447
(045)	2.250	1.600	1.142	0.579

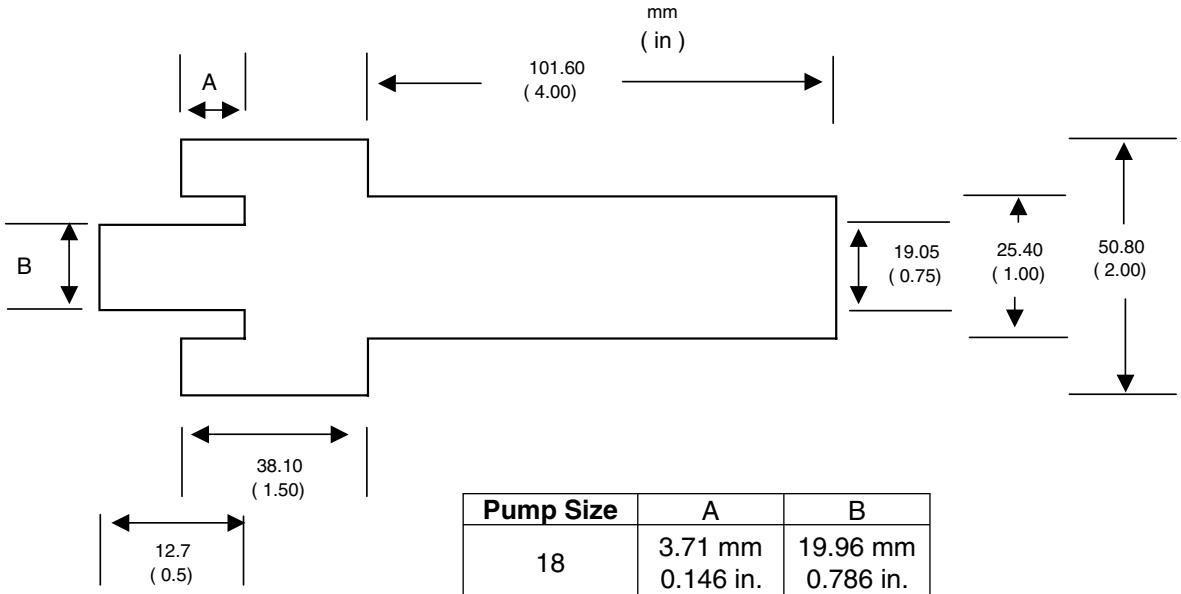


T3 Seal Guard	A	B	C	D	E	F
P18 “01”, “02”, “04” Shafts	76.20 mm 3.00 in.	50.80 mm 2.00 in.	19.05 mm .75 in.	15 deg	28.82 mm 1.135 in.	20.45 mm .805 in.
P18 “06” Shaft	76.20 mm 3.00 in.	50.80 mm 2.00 in.	19.05 mm .75 in.	15 deg	28.82 mm 1.135 in.	16.76 mm .66 in.
P28 / P45 “01”, “02”, “04 Shafts	76.20 mm 3.00 in.	50.80 mm 2.00 in.	19.05 mm .75 in.	15 deg	38.10 mm 1.50 in.	26.00 mm 1.024 in.
P18/ P28 / P45 “08” Shaft	76.20 mm 3.00 in.	50.80 mm 2.00 in.	19.05 mm .75 in.	15 deg	28.82 mm 1.135 in.	22.50 mm .885 in.

T2 Front Bearing P1/PD45 Installation Tool



T5 Rear Bushing Installation Tool



Pump Size	A	B
18	3.71 mm 0.146 in.	19.96 mm 0.786 in.
28	4.00 mm 0.157 in.	21.97 mm 0.865 in.
45	4.00 mm 0.157 in.	24.97 mm 0.983 in.

PUMP TEST PROCEDURE

Test criteria based on hydraulic oil ISO 32 per Parker HF-0 specifications.
Oil temperature: 50°C ± 2°C (120°F ±10°F). **NOTE:** insure that the hydraulic system does not overheat during this test procedure.
Operating speed: 0 - 2300 rpm ± 30 rpm.
Case pressure: Maximum 14.5 psi (1 bar)

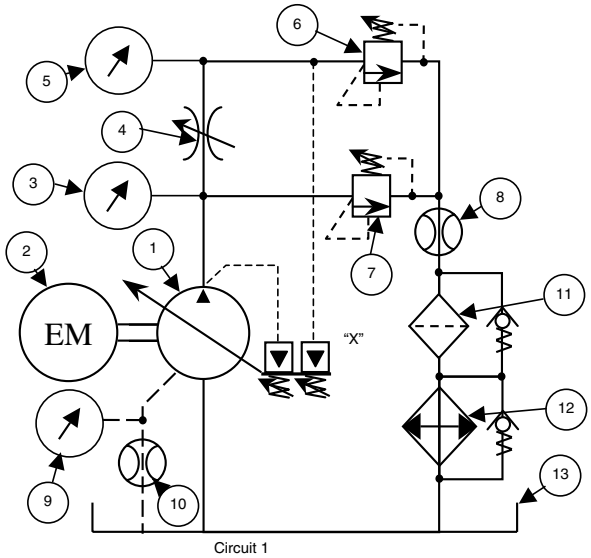
1. Mount pump on test fixture. Insure that shaft alignment is within specified tolerances.
2. Fill case with clean oil. Connect upper drain port to reservoir with no restrictions. Insure other drain ports are properly plugged.
3. Connect inlet and pressure lines. Insure that lines are filled with oil. Refer to circuit below. For units with “L” compensators, connect a suitable pilot line from port “X” to the pump discharge pressure line, down stream of the non-compensating flow valve.
4. Confirm direction of rotation for pump and drive are correct.
5. Reduce the main compensator setting to minimum. For units with “L” compensators, advance the load sense compensator adjustment until it bottoms out, and lock into position.
6. Set maximum volume stop (if included) to full displacement. If minimum volume stop is included, back adjustment all of the way out.
7. If possible, gradually increase pump speed to 1800 ± 30 rpm with no load.
8. Screw in compensator adjusting screw until it bottoms out, with no pressure on system load-relief valve.
9. Break-in pump at times and pressures listed below. Adjust the load-relief valve to the pressure listed for the times indicated. After break-in, reduce compensator setting to 280 bar (4060 psi), and adjust system load relief to cause pump to compensate three times to verify that pump compensates on and off stroke properly.

Time	30 seconds	30 seconds	30 seconds
Pressure	62-69 Bar 900-1000 psi	200-207 Bar 2900-3000 psi	269-276 Bar. 3900-4000 psi

TEST CIRCUIT

1. Test pump
2. Test stand prime mover
3. Pump pressure gauge
4. Non-compensating flow control
5. Load pressure gauge
6. Load relief valve
7. Safety bypass relief valve
8. Main flow meter
9. Case drain pressure gauge
10. Case drain flow meter
11. Filter assembly with bypass
12. Cooler assembly with bypass
13. Reservoir

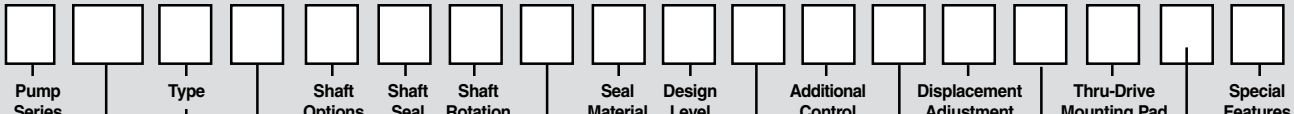
NOTE: Items 4 and 5 are required for load sense pump test.



Circuit 1

PERFORMANCE SPECIFICATIONS PUMP WITH PRESSURE COMPENSATOR				
STEP REFERENCE	CONDITION	018	028	045
1	Rated Speed	1800	1800	1800
4	Output Flow at minimum pressure	32 lpm minimum	49 lpm minimum	80 lpm minimum
5	Output Flow at rated pressure of 280 bar	30 lpm minimum	47 lpm minimum	77 lpm minimum
6	Case leakage at rated pressure of 280 bar	1.6 lpm	2.3 lpm	5.3 lpm
9	Case leakage when compensated at 280 bar	3.75 lpm	3.95 lpm	6.7 lpm
10	Input Torque when compensated at 280 bar	17.5 Nm	21.2 Nm	42 Nm
11	Output Flow when pressure reduced to 273 bar with compensator set at 280 bar	30 lpm minimum	47 lpm minimum	77 lpm minimum

PERFORMANCE SPECIFICATIONS PUMP WITH PRESSURE COMPENSATOR			
STEP REFERENCE	CONDITION	REQUIRED VALUE	MEASURED VALUE
1	Set the pump speed to 1800 RPM	1800 rpm	
2	Increase pump pressure compensator adjustment to maximum.	n/a	
3	Record input oil temperature	43-54 ° C (110 – 130 °F)	
4	Set output load pressure to minimum. Record output flow	see performance chart	
5	Set output load pressure to 280 ± 2 bar (4060 ± 30 psi). Record output flow	see performance chart	
6	Record case leakage	see performance chart	
7	Set output pressure to 290 ± 2 bar (4200 ± 30 psi)	n/a	
8	Set pressure compensator to 280 ± 2 bar (4060 ± 30 psi)	n/a	
9	Record case leakage	see performance chart	
10	Record input torque	see performance chart	
11	Reduce output pressure to 273 ± 2 bar (3960 ± 30 psi). Record output flow	see performance chart	
12	Verify no external leaks	No leakage permitted	



Code	Series
P1	Mobile
PD	Industrial

Code	Displacement
018	**18 cc/rev** (1.10 in³/rev)
028	**28 cc/rev** (1.71 in³/rev)
045	**45 cc/rev** (2.75 in³/rev)

Code	Type
P	Open circuit, variable displacement

Code	Design Level
A	Current Design Series

Code	Seal Material
5	Fluorocarbon

Code	Application
M	Mobile (P1)
S	Industrial (PD)
U*	Universal

* Available on 45 cc , "S" Mounting & Port Option Pumps only.

Code	Shaft Rotation
R	Clockwise
L	Counterclockwise

Code	Shaft Seal
S	Single Shaft Seal

Code	Mounting & Ports See Catalog Table for Complete Information									
	018 Mount	018 Threaded	018 Aux Ports	028 Mount	028 Threaded	028 Aux Ports	045 Mount	045 Threaded	045 4 Bolt Flange	045 Aux Ports
S	82-2 SAE A	SAE 16/12	SAE 4/6	101-2 SAE B	SAE 20/12	SAE 4/8	101-2 SAE B	SAE 24/16	38/25mm Code 61	SAE 4/10
A	82-2 SAE A	M33/27	BSPP 1/4,3/8"	101-2 SAE B	M42x2 M27x2	BSPP 1/4",1/2"	101-2 SAE B	M48x2 M33x2	38/25mm DIN51/25	BSPP 1/4",1/2"
M	ISO	M33/27	M12x1.5, M16x1.5	ISO	M42x2, M27x2	M12x1.5, M22x1.5	ISO	M48x2, M33x2	38/25mm DN51/25	M12x1.5, M22x1.5
B	ISO	M33/27	BSPP 1/4,3/8"	ISO	M42x2, M27x2	BSPP 1/4", 1/2"	ISO	M48x2, M33x2	38/25mm DN51/25	BSPP 1/4", 1/2"

Code	018 Shaft Options	028 Shaft Option	045 Shaft Option
01	SAE A 11T Spline	SAE B-B 15T Spline	SAE B-B 15T Spline
02	SAE 19-1 Key .75" Dia.	SAE Key 1" Dia. B-B	SAE Key 1" Dia. B-B
04	ISO/DIN Key 20mm Dia.	ISO/DIN Key 25mm Dia.	ISO/DIN Key 25mm Dia.
06	SAE A 9T Spline	—	—
08	—	SAE B 13T Spline	SAE B 13T Spline

Code	Control Options
C0	Pressure Limiter, 80-280 bar Adjustment Range
C1	Pressure Limiter, 20-80 bar Adjustment Range
L0	Load sensing, 10-30 bar ΔP and Pressure Limiter 80-280 bar
L2	Load sensing, 10-30 bar ΔP and Pressure Limiter 80-280 bar with bleed orifice
AE	Pilot Operated Pressure Limiter Control with Proportional Electronic Adjustment (12V)
AF	Pilot Operated Pressure Limiter Control with Proportional Electronic Adjustment (24V)
AN*	Pilot Operated Control with ISO-4401 (NG6) Interface and Shipping Cover
AM	Pilot Operated Pressure Limiter Control with Mechanical Adjustment and Vent Port
AL	Load Sense and Pressure Limiter (P'045 Torque Limiter only)

* Not a functional control as shipped . See control description on page 7.

Code	Additional Control Options
0	None
T	Torque Limiter 45cc ALT, AMT only

Code	Port Orientation
E	End Ports
R	Side Ports with Ripple Chamber
T	Side Ports with Thru-Drive 45 only

Code	Displacement Adjustment
0	None
1*	Adjustable Maximum Displacement
2*	Adjustable Minimum Displacement
3*	Adjustable Max & Min Displacement

* Displacement adjustment not available on thru-drive.

Code	Case-to-Inlet Check Valve/Port Type
0	4 Bolt Flange (P'45 Only) / No Case Check
1	4 Bolt Flange (P'45 Only) / With Case Check
2	Threaded Ports / No Case Check
3	Threaded Ports / With Case Check

Code	Thru-Drive Mounting Pad/ Coupling*
0	No Thru-Drive
A	SAE 82-2 (A) Pilot & SAE A 9T Coupling
H	SAE 82-2 (A) Pilot & SAE A 11T Coupling
B	SAE 101-2 (B) Pilot & SAE B 13T Coupling
Q	SAE 101-2 (B) Pilot & SAE B-B 15T Coupling

* For 045 only

Code	Paint
00	No Paint
PB	Black Paint

Code	Special Features
00	No Special Features
M2	Special Modification

CONVERSION FACTORS

DEFINITION & UNIT		
displacement	$in^3/rev \times 16.387 = cm^3/rev$	$cm^3/rev \times 0.06102 = in^3/rev$
flow	gpm x 3.78 = L/min	L/min x 0.2642 = gpm
power	hp x 0.7457 = kW	kW x 1.341 = hp
torque	lb-ft x 1.3567 = Nm	Nm x 0.7376 = lb-ft
pressure	lbs/in^2 (psi) x 0.06895 = bar lbs/in^2 (psi) x 6.895 = kPa	bar x 14.50 = lbs/in^2 (psi) kPa x 0.1450 = lbs/in^2 (psi)
weight	lb x 0.4536 = kg	kg x 2.205 = lbs
force	lb x 4.448 = N	N x 0.2248 = lbs
volume	in3 x 16.387 = cm^3	cm3 x 0.06102 = in^3
area	in2 x 6.452 = cm^2	cm2 x 0.1550 = in^2
length	in x 25.4 = mm	mm x 0.03937 = in
temperature	$\frac{\text{degree F-32}}{1.8}$ = °C	1.8 x C+32 = °F
viscosity	cSt x 1.0 = mm^2/sec SSU = cSt x 4.25 + 14	mm^2/sec x 1.0 = cSt 20 cSt = 99 SSU

FLUID POWER FORMULAS

Pump input torque	lbs. in.	$\frac{\text{pressure(psi) x displacement } (in^3/rev)}{2\pi \text{ x mech. eff.}}$
Pump input power	hp	$\frac{\text{rpm x } (in^3/rev) \text{ x (psi)}}{395934 \text{ x overall eff.}}$
Pump output flow	U.S. gpm	$\frac{\text{rpm x } (in^3/rev) \text{ x volumetric eff.}}{231}$
Fluid motor speed	rpm	$\frac{231 \text{ x flow rate(U.S. gpm) x volumetric eff.}}{\text{displacement } (in^3/rev)}$
Fluid motor torque	lbs. in.	$\frac{\text{pressure(psi) x displacement } (in^3/rev) \text{ x mech. eff.}}{2\pi}$
Fluid motor power	hp	$\frac{\text{rpm x } (in^3/rev) \text{ x (psi) x overall eff.}}{395934}$
(metric)		
Pump input torque	Nm	$\frac{\text{pressure(bar) x displacement } (cm^3/rev)}{20\pi \text{ x mech. eff.}}$
Pump input power	kW	$\frac{\text{rpm x } (cm^3/rev) \text{ x (bar)}}{600000 \text{ x overall eff.}}$
Pump output flow	Lpm	$\frac{\text{rpm x } (cm^3/rev) \text{ x volumetric eff.}}{1000}$
Fluid motor speed	rpm(min^{-1}) (tr/mn)	$\frac{1000 \text{ x flow rate (Lpm) x volumetric eff.}}{\text{displacement } (cm^3/rev)}$
Fluid motor torque	Nm	$\frac{\text{pressure(bar) x displacement } (cm^3/rev) \text{ x mech. eff.}}{20\pi}$
Fluid motor power	kW	$\frac{\text{rpm x } (cm^3/rev) \text{ x (bar) x overall eff.}}{600000}$

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3. Delivery Dates; Title and Risk; Shipment. All delivery dates are approximate and Seller shall not be responsible for any damages resulting from any delay. Regardless of the manner of shipment, title to any products and risk of loss or damage shall pass to Buyer upon tender to the carrier at Seller's facility (i.e., when it's on the truck, it's yours). Unless otherwise stated, Seller may exercise its judgment in choosing the carrier and means of delivery. No deferment of shipment at Buyers' request beyond the respective dates indicated will be made except on terms that will indemnify, defend and hold Seller harmless against all loss and additional expense. Buyer shall be responsible for any additional shipping charges incurred by Seller due to Buyer's changes in shipping, product specifications or in accordance with Section 13, herein.

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5. Claims; Commencement of Actions. Buyer shall promptly inspect all Products upon delivery. No claims for shortages will be allowed unless reported to the Seller within 10 days of delivery. No other claims against Seller will be allowed unless asserted in writing within 60 days after delivery or, in the case of an alleged breach of warranty, within 30 days after the date within the warranty period on which the defect is or should have been discovered by Buyer. Any action based upon breach of this agreement or upon any other claim arising out of this sale (other than an action by Seller for any amount due to Seller from Buyer) must be commenced within thirteen months from the date of tender of delivery by Seller or, for a cause of action based upon an alleged breach of warranty, within thirteen months from the date within the warranty period on which the defect is or should have been discovered by Buyer.

6. LIMITATION OF LIABILITY. UPON NOTIFICATION, SELLER WILL, AT ITS OPTION, REPAIR OR REPLACE A DEFECTIVE PRODUCT, OR REFUND THE PURCHASE PRICE. IN NO EVENT SHALL SELLER BE LIABLE TO BUYER FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF, OR AS THE RESULT OF, THE SALE, DELIVERY, NON-DELIVERY, SERVICING, USE OR LOSS OF USE OF THE PRODUCTS OR ANY PART THEREOF, OR FOR ANY CHARGES OR EXPENSES OF ANY NATURE INCURRED WITHOUT SELLER'S WRITTEN CONSENT, EVEN IF SELLER HAS BEEN NEGLIGENT, WHETHER IN CONTRACT, TORT OR OTHER LEGAL THEORY. IN NO EVENT SHALL SELLER'S LIABILITY UNDER ANY CLAIM MADE BY BUYER EXCEED THE PURCHASE PRICE OF THE PRODUCTS.

7. Contingencies. Seller shall not be liable for any default or delay in performance if caused by circumstances beyond the reasonable control of Seller.

8. User Responsibility. The user, through its own analysis and testing, is solely responsible for making the final selection of the system and Product and assuring that all performance, endurance, maintenance, safety and warning requirements of the application are met. The user must analyze all aspects of the application and follow applicable industry standards and Product information. If Seller provides Product or system options, the user is responsible for determining that such data and specifications are suitable and sufficient for all applications and reasonably foreseeable uses of the Products or systems.

9. Loss to Buyer's Property. Any designs, tools, patterns, materials, drawings, confidential information or equipment furnished by Buyer or any other items which become Buyer's property, may be considered obsolete and may be destroyed by Seller after two consecutive years have elapsed without Buyer placing an order for the items which are manufactured using such property. Seller shall not be responsible for any loss or damage to such property while it is in Seller's possession or control.

10. Special Tooling. A tooling charge may be imposed for any special tooling, including without limitation, dies, fixtures, molds and patterns, acquired to manufacture Products. Such special tooling shall be and remain Seller's property notwithstanding payment of any charges by Buyer. In no event will Buyer acquire any interest in apparatus belonging to Seller which is utilized in the manufacture of the Products, even if such apparatus has been specially converted or adapted for such manufacture and notwithstanding any charges paid by Buyer. Unless otherwise agreed, Seller shall have the right to alter, discard or otherwise dispose of any special tooling or other property in its sole discretion at any time.

11. Buyer's Obligation; Rights of Seller. To secure payment of all sums due or otherwise, Seller shall retain a security interest in the goods delivered and this agreement shall be deemed a Security Agreement under the Uniform Commercial Code. Buyer authorizes Seller as its attorney to execute and file on Buyer's behalf all documents Seller deems necessary to perfect its security interest. Seller shall have a security interest in, and lien upon, any property of Buyer in Seller's possession as security for the payment of any amounts owed to Seller by Buyer.

12. Improper Use and Indemnity. Buyer shall indemnify, defend, and hold Seller harmless from any claim, liability, damages, lawsuits, and costs (including attorney fees), whether for personal injury, property damage, patent, trademark or copyright infringement or any other claim, brought by or incurred by Buyer, Buyer's employees, or any other person, arising out of: (a) improper selection, improper application or other misuse of Products purchased by Buyer from Seller; (b) any act or omission, negligent or otherwise, of Buyer; (c) Seller's use of patterns, plans, drawings, or specifications furnished by Buyer to manufacture Product; or (d) Buyer's failure to comply with these terms and conditions. Seller shall not indemnify Buyer under any circumstance except as otherwise provided.

13. Cancellations and Changes. Orders shall not be subject to cancellation or change by Buyer for any reason, except with Seller's written consent and upon terms that will indemnify, defend and hold Seller harmless against all direct, incidental and consequential loss or damage. Seller may change product features, specifications, designs and availability with notice to Buyer.

14. Limitation on Assignment. Buyer may not assign its rights or obligations under this agreement without the prior written consent of Seller.

15. Entire Agreement. This agreement contains the entire agreement between the Buyer and Seller and constitutes the final, complete and exclusive expression of the terms of the agreement. All prior or contemporaneous written or oral agreements or negotiations with respect to the subject matter are herein merged.

16. Waiver and Severability. Failure to enforce any provision of this agreement will not waive that provision nor will any such failure prejudice Seller's right to enforce that provision in the future. Invalidation of any provision of this agreement by legislation or other rule of law shall not invalidate any other provision herein. The remaining provisions of this agreement will remain in full force and effect.

17. Termination. This agreement may be terminated by Seller for any reason and at any time by giving Buyer thirty (30) days written notice of termination. In addition, Seller may by written notice immediately terminate this agreement for the following: (a) Buyer commits a breach of any provision of this agreement (b) the appointment of a trustee, receiver or custodian for all or any part of Buyer's property (c) the filing of a petition for relief in bankruptcy of the other Party on its own behalf, or by a third party (d) an assignment for the benefit of creditors, or (e) the dissolution or liquidation of the Buyer.

18. Governing Law. This agreement and the sale and delivery of all Products hereunder shall be deemed to have taken place in and shall be governed and construed in accordance with the laws of the State of Ohio, as applicable to contracts executed and wholly performed therein and without regard to conflicts of laws principles. Buyer irrevocably agrees and consents to the exclusive jurisdiction and venue of the courts of Cuyahoga County, Ohio with respect to any dispute, controversy or claim arising out of or relating to this agreement. Disputes between the parties shall not be settled by arbitration unless, after a dispute has arisen, both parties expressly agree in writing to arbitrate the dispute.

19. Indemnity for Infringement of Intellectual Property Rights. Seller shall have no liability for infringement of any patents, trademarks, copyrights, trade dress, trade secrets or similar rights except as provided in this Section. Seller will defend and indemnify Buyer against allegations of infringement of U.S. patents, U.S. trademarks, copyrights, trade dress and trade secrets ("Intellectual Property Rights"). Seller will defend at its expense and will pay the cost of any settlement or damages awarded in an action brought against Buyer based on an allegation that a Product sold pursuant to this Agreement infringes the Intellectual Property Rights of a third party. Seller's obligation to defend and indemnify Buyer is contingent on Buyer notifying Seller within ten (10) days after Buyer becomes aware of such allegations of infringement, and Seller having sole control over the defense of any allegations or actions including all negotiations for settlement or compromise. If a Product is subject to a claim that it infringes the Intellectual Property Rights of a third party, Seller may, at its sole expense and option, procure for Buyer the right to continue using the Product, replace or modify the Product so as to make it noninfringing, or offer to accept return of the Product and return the purchase price less a reasonable allowance for depreciation. Notwithstanding the foregoing, Seller shall have no liability for claims of infringement based on information provided by Buyer, or directed to Products delivered hereunder for which the designs are specified in whole or part by Buyer, or infringements resulting from the modification, combination or use in a system of any Product sold hereunder. The foregoing provisions of this Section shall constitute Seller's sole and exclusive liability and Buyer's sole and exclusive remedy for infringement of Intellectual Property Rights.

20. Taxes. Unless otherwise indicated, all prices and charges are exclusive of excise, sales, use, property, occupational or like taxes which may be imposed by any taxing authority upon the manufacture, sale or delivery of Products.

21. Equal Opportunity Clause. For the performance of government contracts and where dollar value of the Products exceed $10,000, the equal employment opportunity clauses in Executive Order 11246, VEVRAA, and 41 C.F.R. §§ 60-1.4(a), 60-741.5(a), and 60-250.4, are hereby incorporated.

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